

## AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application.

1. (Original) A method for fabricating a liquid containing intermixed nanoparticulate elements of groups IB and IIIA and optionally VIA, comprising the steps of:  
forming elemental non-oxide metal nanoparticles containing elements from group IB; and  
forming elemental non-oxide metal nanoparticles from group IIIA; and  
optionally forming elemental non-oxide nanoparticles from group VIA;  
intermixing the elemental non-oxide nanoparticles from groups IB and IIIA; and  
optionally VIA, wherein the particles are in a desired particle size range of between about 0.1 nm and about 500 nm in diameter, wherein, for each element metal, a majority of the mass of the elemental metal nanoparticles range in size from no more than about 40% above or below an average particle size, or, if the average particle size is less than about 5 nanometers, from no more than about 2 nanometers above or below the average particle size; and  
mixing the particles to form a liquid that serves as an ink.
2. (Original) The method of claim 1 wherein the group IB element is copper (Cu), the group IIIA element is indium and optionally includes gallium) and the group VIA element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S in the liquid is approximately  $\text{CuIn}_{1-x}\text{Ga}_x(\text{S or Se})_2$ , where x is between 0 and 1.
3. (Original) The method of claim 1 further comprising coating the elemental non-oxide metal nanoparticles with a surfactant or polymer.
4. (Original) The method of claim 1 wherein forming the elemental non-oxide metal nanoparticles includes condensing a metal vapor.
5. (Original) The method of claim 4 wherein the metal vapor includes Cu and/or In, and optionally Se.
6. (Original) The method of claim 3 wherein forming the elemental non-oxide metal nanoparticles includes laser ablation, mechanical milling, grinding, nucleation from vapor, exploding wires by electrical current surge, thermal decomposition of organometallic compounds, sonolysis, pulse radiolysis, electrochemical reduction or chemical reduction.
7. (Original) The method of claim 1 wherein the liquid is formed by mixture with water.

- 2 8. (Original) The method of claim 1 wherein the liquid is formed by mixture with organic  
3 solvent.
- 4 9. (Original) The method of claim 1, further comprising adding a capping agent to the  
5 elemental nanoparticles, wherein the capping agent selected from the group of  
6 phosphines, amines, alcohols, thiols, ethers, water and glycols, trioctylphosphine oxide,  
7 trioctylphosphine, triphenylphosphine, pyridine, methanol, ethanol, propanol, butanol,  
8 ethane thiol, tetrahydrofuran, ethers, ammonia, methyl amine, ethylamine,  
9 ethylenediamine, and acetonitrile.
- 10 10. (Original) The method of claim 1, further comprising adding a binder to the elemental  
11 nanoparticles.
- 1 11. (Original) The method of claim 1, further comprising adding a fluxing agent to the  
2 elemental nanoparticles.
- 1 12. (Original) The method of claim 1, further comprising adding one or more surfactants,  
2 polymers, dispersants, binders, modifiers, detergents or additives to the elemental  
3 nanoparticles.
- 1 13. (Original) A method for fabricating a liquid containing intermixed elements of groups IB  
2 and IIIA, and optionally VIA, comprising the steps of:  
3 forming non-oxide quantum nanoparticles containing elements from group IB; and  
4 forming non-oxide quantum nanoparticles containing elements from group IIIA; and  
5 optionally forming non-oxide quantum nanoparticles containing elements from group  
6 VIA;  
7 intermixing the non-oxide quantum nanoparticles from groups IB and IIIA and optionally  
8 VIA wherein the non-oxide quantum nanoparticles are in a desired particle size range of  
9 between about 0.1 nm and about 10 nm in diameter, wherein, for each element, a majority  
10 of the mass of the non-oxide quantum nanoparticles range in size from no more than  
11 about 40% above or below an average particle size, or, if the average particle size is less  
12 than about 5 nanometers, from no more than about 2 nanometers above or below the  
13 average particle size ; and  
14 mixing the non-oxide nanoparticles to form a liquid that serves as an ink.
- 15 14. (Original) The method of claim 13 wherein the non-oxide quantum nanoparticles are  
16 quantum dots, quantum wires, quantum wells, or quantum rods.

- 17 15. (Original) The method of claim 13 wherein the group IB element is copper (Cu), the  
18 group IIIA element is indium and optionally includes gallium) and the group VIA  
19 element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S  
20 in the liquid is approximately  $\text{CuIn}_{1-x}\text{Ga}_x(\text{S or Se})_2$ , where x is between 0 and 1.
- 1 16. (Original) The method of claim 13 wherein forming non-oxide quantum nanoparticles  
2 includes a reaction of the type:  
3  $\text{CuCl} + \text{InCl}_3 (+\text{GaI}_3) + \text{TOPSe(S)} + \text{TOPO} \rightarrow \text{Cu(Ga, In)Se(S)}_2$ .
- 1 17. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes performing a reaction of the type:  
3  $\text{CuCl (or CuI or CuCl}_2) + \text{InCl}_3 \text{ (or InI}_3 \text{ or GaI}_3) + \text{Na}_2\text{Se} + \text{ligand/capping agent} \rightarrow$   
4  $\text{Cu(Ga,In)Se}_2$ .
- 1 18. (Original) The method of claim 13 wherein the ligand/capping agent is selected from the  
2 group of phosphines, amines, alcohols, thiols, ethers, water and glycols,  
3 trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine, methanol,  
4 ethanol, propanol, butanol, ethane thiol, tetrahydrofuran, ethers, ammonia, methyl amine,  
5 ethylamine, ethylenediamine, and acetonitrile.
- 1 19. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes reacting a single-source precursor to form particles of IB-IIIa-VIA  
3 material.
- 1 20. (Original) The method of claim 19 wherein the single-source precursor is  
2  $(\text{PPh}_3)_2\text{CuIn(SET)}_4$  or  $(\text{PPh}_3)_2\text{CuIn(SePh)}_4$ .
- 1 21. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes spray co-precipitation of two or more reactants.
- 1 22. (Original) The method of claim 21 wherein one of the two or more reactants is selected  
2 from the group of metal halides, metal acetates, metal sulfates, metal nitrates, metal  
3 alcoholates, metal carbonates, metal phenolates, metal hydroxides, and organometallics.
- 1 23. (Original) The method of claim 22 wherein the two or more reactants include one or  
2 more reactants of the type X/Hal, where X is Cu or In and Hal is chlorine (Cl) or iodine  
3 (I).

- 1 24. (Original) The method of claim 23 wherein the two or more reactants further include  
2 thiourea or selenourea.
- 1 25. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes performing a reaction of the type:  
3  $(\text{IB})(\text{Et}_2\text{CN}(\text{VIA}))_2 + \text{TOPO} \rightarrow \text{IB-VIA}$
- 1 26. (Original) The method of claim 25 wherein IB is Cu and VIA is Se or S.
- 1 27. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes performing a reaction of the type:  
3  $(\text{IB})(\text{Hal}) + \text{Na}_2(\text{VIA}) + \text{ligand/capping agent} \rightarrow \text{IB-VIA} + 2\text{Na}(\text{Hal})$
- 1 28. (Original) The method of claim 27 wherein the ligand/capping agent is selected from the  
2 group of trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine,  
3 alcohols (methanol, ethanol, propanol, butanol), ethane thiol, tetrahydrofuran, ethers,  
4 ammonia, amines (methyl amine, ethylamine, ethylenediamine) and acetonitrile.
- 1 29. (Original) The method of claim 27 wherein the reaction is of the type:  
2  $\text{CuCl}_2 + \text{Na}_2\text{Se} + \text{Pyridine} \rightarrow \text{CuSe} + 2\text{NaI}$ .
- 1 30. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes performing a reaction of the type:  
3  $(\text{IB})(\text{Hal}) + (\text{IIIA})(\text{Hal}) + \text{Na}_2(\text{VIA}) + \text{Ligand/Capping Agent} \rightarrow \text{IB-IIIA-VIA}$
- 1 31. (Original) The method of claim 30 wherein the reaction is of the type:  
2  $2\text{InI}_3 + 3\text{Na}_2\text{Se} \rightarrow \text{In}_2\text{Se}_3 + 6\text{NaI}$ .
- 1 32. (Original) The method of claim 13 wherein forming a mixture of non-oxide quantum  
2 nanoparticles includes sonochemical synthesis of nanoparticles particles containing Se  
3 with Cu or In or Ga.
- 1 33. (Original) The method of claim 13 wherein forming non-oxide quantum nanoparticles  
2 includes preparing metal nanoparticles containing elements of groups IB, IIIA, VIA or a  
3 IB-IIIA-VIA alloy, by laser ablation, nucleation from vapor, exploding wires by electrical  
4 current surge, thermal decomposition of organometallic compounds, sonolysis, pulse  
5 radiolysis, electrochemical reduction or chemical reduction.
- 6 34. (Original) The method of claim 13 wherein the liquid is formed by mixture with water.

- 7 35. (Original) The method of claim 13 wherein the liquid is formed by mixture with organic  
8 solvent.
- 9 36. (Original) The method of claim 13, further comprising adding a capping agent to the  
10 non-oxide quantum nanoparticles.
- 11 37. (Original) The method of claim 13, further comprising adding a binder to the non-oxide  
12 quantum nanoparticles.
- 1 38. (Original) The method of claim 13, further comprising adding a fluxing agent to the non-  
2 oxide quantum nanoparticles.
- 1 39. (Original) The method of claim 13, further comprising adding one or more surfactants,  
2 polymers, dispersants, binders, modifiers, detergents or additives to the non-oxide  
3 quantum nanoparticles.
- 4 40. (Original) A method for fabricating a liquid containing intermixed elements of groups IB  
5 and IIIA and optionally VIA, comprising the steps of:  
6 forming nanoparticles from group IB; and  
7 intermixing the nanoparticles from group IB with elements from group IIIA, wherein the  
8 elements from group IIIA are in molten form, wherein the nanoparticles from group IB  
9 comprise particles in a desired particle size range of between about 0.1 nm and about 500  
10 nm in diameter, wherein a majority of the mass of the nanoparticles range in size from no  
11 more than about 40% above or below an average particle size, or, if the average particle  
12 size is less than about 5 nanometers, from no more than about 2 nanometers above or  
13 below the average particle size; and  
14 mixing the nanoparticles with the molten elements to form a liquid that serves as an ink.
- 15 41. (Original) The method of claim 40 wherein the group IB element is copper (Cu), the  
16 group IIIA element is indium and optionally includes gallium) and the group VIA  
17 element is selenium (Se) or sulfur (S) and a stoichiometric ratio of the Cu, In and Se or S  
18 in the liquid is approximately  $\text{CuIn}_{1-x}\text{Ga}_x(\text{S or Se})_2$ , where x is between 0 and 1.
- 1 42. (Original) The method of claim 41 wherein a majority of the group IB nanoparticles  
2 range in size from no more than about 40% above or below an average nanoparticle size,  
3 or, if the average nanoparticle size is less than about 5 nanometers, from no more than  
4 about 2 nanometers above or below the average nanoparticle size.

- 1 43. (Original) The method of claim 40, further comprising adjusting the temperature of the  
2 Cu-In-Ga mixture until a solid forms and then grinding the solid to form nanoparticles.
- 1 44. (Original) The method of claims 1, 13, or 40 further comprising the step of capping the  
2 nanoparticles with an organic material.
- 1 45. (Original) The method of claim 44 wherein the organic material is a small molecule with  
2 low boiling point.
- 1 46. (Original) The method of claim 44 wherein the organic material is selected from the  
2 group of trioctylphosphine oxide, trioctylphosphine, triphenylphosphine, pyridine,  
3 alcohols (methanol, ethanol, propanol, butanol), ethane thiol, tetrahydrofuran, ethers,  
4 ammonia, amines (methyl amine, ethylamine, ethylenediamine) and acetonitrile.
- 1 47. (Original) The method of claims 44 wherein the organic material is pyridine.
- 1 48. (Original) The method of claim 1, 13, or 40 wherein forming a mixture of non-oxide  
2 nanoparticles includes selecting particles in the desired particle size range.
- 1 49. (Original) The method of claim 48, wherein selecting nanoparticles in the desired size  
2 range includes adjusting one or more parameters of a reaction that forms the  
3 nanoparticles, size-selective precipitation, or ultrafiltration.
- 1 50. (Original) The method of claims 1, 13 or 40 further comprising adding a water-  
2 compatible dispersant to the liquid.
- 1 51. (Original) The method of claims 1, 13, or 40 wherein forming the non-oxide  
2 nanoparticles includes preparing particles in a non-oxygen atmosphere.
- 1 52. Canceled.
- 1 53. Canceled.
- 1 54. Canceled.
- 1 55. Canceled.
- 1 56. Canceled.
- 1 57. Canceled.

1 58. Canceled.

1 59. Canceled.

1 60. Canceled.

1 61. (Amended) A method for fabricating a photovoltaic cell active layer containing a IB-  
2 IIIA-VIA alloy, comprising the steps of:  
3 forming a liquid ink containing intermixed nanoparticles of elements from groups IB,  
4 IIIA and optionally VIA, using the method of claim 1, 13, 40 or ~~52~~75; spreading a film  
5 of the liquid onto a substrate;  
6 annealing the film to form the active layer; and  
7 exposing the film to Se-containing vapor.

1 62. (Original) The method of claim 61, wherein the IB-IIIA-VIA alloy is an alloy of copper  
2 (Cu) with indium (In) or Gallium (Ga) and selenium (Se) or sulfur (S) having a  
3 stoichiometric ratio of the Cu, In and Se or S of approximately  $\text{CuIn}_{1-x}\text{Ga}_x(\text{S or Se})_2$ ,  
4 wherein x is between 0 and 1.

1 63. (Original) The method of claim 61 wherein the substrate is a polymer or metallized  
2 polymer.

1 64. (Original) The method of claim 61, wherein annealing the film includes heating the film  
2 to a temperature between about 200°C and about 600°C.

1 65. (Original) The method of claim 61, wherein the film is spread onto the substrate and/or  
2 annealed in a roll-to-roll production system.

1 66. (Original) The method of claim 61, further comprising, winding the substrate into a coil  
2 and exposing the coiled substrate to selenium vapor.

1 67. (Original) The method of claim 61 wherein annealing the substrate includes winding the  
2 substrate into a coil and heating the coiled substrate.

1 68. (Original) The method of claim 61, further comprising winding the substrate into a coil  
2 and depositing a layer of material on one or more surfaces of the coiled substrate.

1 69. (Original) The method of claim 61 wherein the layer of material includes a transparent  
2 conductive oxide.

1 70. (Original) The method of claim 61 wherein forming the liquid, spreading the film of the  
2 liquid and annealing the film does not include the use of  $H_2Se$  to selenize the particles,  
3 film or active layer.

1 71. (Original) The method of claim 61 wherein forming the liquid, spreading the film of the  
2 liquid and annealing the film does not include reduction of the particles, film or active  
3 layer with  $H_2$ .

4 72. (Amended) A photovoltaic cell, comprising:  
5 a base electrode;  
6 a top electrode; and  
7 an active layer disposed between the base electrode and top electrode, the active layer  
8 containing a IB-III A-VIA alloy, wherein the active layer is formed from a liquid ink  
9 containing nanoparticles of elements from groups IB, III A and optionally VIA, using the  
10 method of claim 1, 13, 50 or ~~52~~75.

1 73. (Original) The cell of claim 72 wherein at least one of the base electrode and top  
2 electrode is transparent.

1 74. (Original) The cell of claim 72 further comprising a layer of cadmium sulfide ( $CdS$ ), zinc  
2 sulfide ( $ZnS$ ), or zinc selenide ( $ZnSe$ ) or some combination of two or more of these  
3 disposed between the active layer and the top electrode.

1 75. (New) A method comprising:  
2 providing a suspension comprised of one or more liquid metals, wherein the one or more  
3 liquid metals comprises of at least one group III A based material;  
4 providing a plurality of nanoparticles, wherein the nanoparticles comprise of at least one  
5 group IB based material; and  
6 mixing the nanoparticles and the suspension to form an ink configured to be processed  
7 into a photovoltaic absorber layer.

1 76. (New) The method of claim 75 wherein the suspension comprises a first liquid and a  
2 second liquid, wherein the first liquid comprises the one or more liquid metals.

1 77. (New) The method of claim 76 wherein the second liquid comprises a solvent.

1 78. (New) The method of claim 76 wherein the second liquid comprises an organic solvent.

- 1 79. (New) The method of claim 76 wherein the first liquid in the suspension is not mixable  
2 with the second liquid.
- 1 80. (New) The method of claim 75 wherein the suspension comprises a mixture of two or  
2 more immiscible liquids wherein one liquid comprises one or more liquid metals  
3 dispersed in the other liquid.
- 1 81. (New) The method of claim 75 wherein the suspension comprises an emulsion of one or  
2 more liquid metals in at least one carrier liquid.
- 1 82. (New) The method of claim 75 wherein the one or more liquid metals comprises of a  
2 molten mixture of Gallium and/or Indium.
- 1 83. (New) The method of claim 75 wherein the nanoparticles are elemental nanoparticles.
- 1 84. (New) The method of claim 75 wherein the nanoparticles are binary alloy nanoparticles.